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Effects of Salinity on the Growth of Eggplant (*Solanum melongena* L.)

Abd Rahman, Nur Ashikin, & Shahruddin, Shafeeqa*

Agricultural Science Department, Faculty of Technical and Vocational, Universiti Pendidikan Sultan Idris, 35900, Tanjong Malim, Perak, MALAYSIA

*Corresponding author: shafeeqa@ftv.upsi.edu.my

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Abstract: This study investigated the effects of varying salinity levels on the growth performance of eggplant (*Solanum melongena* L.). Four treatments were applied: control (0.03 ppt), low salinity (3 ppt), moderate salinity (6 ppt), and high salinity (9 ppt). The experiment was conducted over five months under rain-shelter conditions at Universiti Pendidikan Sultan Idris, employing a Randomized Complete Block Design (RCBD) with three replications and 60 plants in total. Growth parameters evaluated included plant height, canopy area, number of leaves, leaf surface area, and root length. Data were analyzed using ANOVA and LSD tests at a significance level of $P \leq 0.05$. The results revealed that salinity significantly ($P \leq 0.01$) affected all growth parameters. Plants exposed to higher salinity levels exhibited stunted growth and reduced biomass accumulation. The findings indicate that *S. melongena* can tolerate salinity up to 3 ppt, although mild growth inhibition may still occur. These results provide useful insights into the salinity tolerance thresholds of eggplant for future cultivation in saline-prone environments.

Keywords: salinity, eggplant, growth parameters, *Solanum melongena* L., tolerance threshold

1. Introduction

Soil salinity is one of the most severe environmental constraints affecting global agricultural productivity. It is estimated that over 20% of irrigated land worldwide is impacted by salinity, with this figure increasing due to unsustainable irrigation practices, climate change, and sea level rise (FAO, 2021). Salinity stress adversely affects plant growth and development by causing osmotic stress, ion toxicity, and nutritional imbalances, which in turn limit water and nutrient uptake, disturb metabolic processes, and reduce photosynthetic efficiency (Munns & Tester, 2008; Shrivastava & Kumar, 2015; Zörb et al., 2019).

In Southeast Asia, including Malaysia, soil salinity is currently considered a minor but emerging issue, particularly in coastal and lowland agricultural zones. The expansion of agriculture into marginal lands, coupled with rising sea levels and the increasing use of saline water for irrigation, may intensify the problem in the near future (Roslan et al., 2019). Therefore, understanding how economically important crops respond to salinity stress is critical to ensure sustainable crop production under changing environmental conditions.

Eggplant (*Solanum melongena* L.), also known as brinjal or aubergine, is a warm-season vegetable crop of considerable nutritional and economic value. It is widely cultivated in tropical and subtropical regions, including India, China, Southeast Asia, and the Mediterranean basin (Frary et al., 2007; Daunay et al., 2021). Eggplant fruits are rich in fiber, vitamins, phenolic compounds, and antioxidants, and their consumption is associated with various health benefits such as cardiovascular protection and anti-inflammatory effects (Kashyap et al., 2003; Kumar et al., 2022). Despite its adaptability to various agro-climatic zones, *S. melongena* is moderately sensitive to salinity, especially during seedling and vegetative stages (Unlukara et al., 2010; Heuer et al., 1986).

Previous studies report contradictory findings regarding eggplant's salinity tolerance. While some researchers have classified it as moderately tolerant (Savvas & Lenz, 1996), others have reported considerable growth inhibition under saline conditions, especially in terms of root elongation, leaf development, and fruit set (Santa-Cruz et al., 2002; Akinci et al., 2004; Hasanuzzaman et al., 2021). High salt concentrations affect the water potential gradient, thereby reducing water uptake and inducing osmotic stress, which in turn leads to stomatal closure, reduced gas exchange, and impaired photosynthesis (Chaudhary et al., 2022).

*Corresponding author: shafeeqa@ftv.upsi.edu.my

Moreover, salinity triggers ion toxicity, particularly from excessive accumulation of sodium (Na^+) and chloride (Cl^-) ions, which interfere with the uptake of essential nutrients such as potassium (K^+), calcium (Ca^{2+}), and magnesium (Mg^{2+}), thereby disturbing cellular homeostasis (Maathuis, 2006; Jha et al., 2023). These ion imbalances impair enzyme activities, membrane integrity, and overall plant metabolism, ultimately leading to stunted growth and lower yields. As such, assessing the impact of salinity on different eggplant traits can provide insights into plant adaptability and help identify potential thresholds of tolerance for sustainable cultivation in salt-affected regions.

Given the increasing global concern on food security and climate-resilient agriculture, there is a pressing need to evaluate how crops like eggplant respond to different salinity regimes. This study aims to assess the morphological responses of eggplant (*Solanum melongena* L.) to varying salinity levels under controlled field conditions, focusing on key growth parameters including plant height, leaf area, number of leaves, root length, and canopy development. The findings are expected to contribute to the development of effective salinity management strategies for vegetable production in regions threatened by salt-affected soils.

2. Materials and Methods

2.1 Experimental Site

The study was conducted at Field A, Department of Agricultural Science, Universiti Pendidikan Sultan Idris (UPSI), Proton City, Malaysia. The experiment lasted five months under semi-controlled conditions using a rain-shelter setup.

2.2 Plant Material and Growth Media

One hybrid variety of *Solanum melongena* L. was used. Seeds were germinated in trays and later transplanted into medium-sized polybags (14” × 14”) containing a 3:1 soil mixture of loam, sand, and organic matter. Each polybag was arranged under a rain shelter to prevent dilution or alteration of salinity treatments from rainwater.

2.3 Experimental Design

The study followed a Randomized Complete Block Design (RCBD) with four salinity treatments:

- Control (TC: 0.03 ppt),
- T1: 3 ppt,
- T2: 6 ppt, and
- T3: 9 ppt.

Each treatment had three replicates, with five plants per replicate, totaling 60 plants. Salinity treatments were administered daily by watering each plant with the corresponding saline solution, prepared by dissolving NaCl in water and verified using a multi-parameter EC meter.

2.4 Growth Measurement

Growth performance of *Solanum melongena* L. was assessed through several morphological parameters that are commonly used to evaluate the physiological impact of abiotic stress, particularly salinity. The parameters measured included plant height, canopy area, number of leaves, leaf surface area, and root length. These measurements were recorded weekly over an eight-week observation period, with the exception of root length, which was measured only once at the end of the study (week 18).

Plant height (cm) was measured from the base of the stem at the soil surface to the apex of the main shoot. This parameter served as an indicator of vertical vegetative growth and overall plant vigor under different salinity levels. Changes in plant height can reflect the plant’s ability to elongate under stress conditions, which is often hindered by osmotic and ionic stress induced by saline environments (Munns & Tester, 2008).

Canopy area (cm^2) was evaluated by measuring the horizontal spread of the plant’s foliage. The canopy area represents the extent of above-ground vegetative development and is directly related to the light interception potential and photosynthetic capacity of the plant. Reduction in canopy size under salinity stress often corresponds to reduced cell expansion and leaf area development (Parida & Das, 2005).

Number of leaves per plant was counted manually for each observation. This trait is a useful metric for determining the plant’s response to salinity in terms of leaf retention and new leaf initiation. Leaf production is known to decline under salt stress due to inhibition of meristematic activity and the early senescence of older leaves (Santa-Cruz et al., 2002).

Leaf surface area (cm^2) was estimated by measuring the length and width of fully expanded leaves and applying a species-specific correction factor to calculate the total photosynthetic surface. Leaf surface area is crucial for evaluating the plant’s capability to assimilate carbon through photosynthesis. Under high salinity, leaf area is typically reduced as a result of both diminished cell division and leaf expansion, often linked to impaired water uptake (Zörb et al., 2019).

Root length (cm) was measured at the conclusion of the experiment by carefully uprooting the plants and measuring the primary root from the base of the stem to the tip. Root development is critical for plant adaptation to salinity, as it influences water and nutrient absorption. High salinity levels are known to inhibit root elongation, impairing the plant's ability to support above-ground growth (Jeannette et al., 2002; Hakim et al., 2010).

All growth measurements were recorded using standardized protocols to ensure consistency across treatments and replications. These parameters collectively provided a comprehensive assessment of the physiological responses of eggplant to increasing salinity stress.

2.5 Statistical Analysis

Data were subjected to analysis of variance (ANOVA) using Statistical Analysis Software (SAS), and treatment means were compared using the Least Significant Difference (LSD) test at a 0.05 probability level.

3. Results and Discussion

3.1 Effect of Salinity on Final Growth Parameters

Significant effects of salinity treatments on all measured growth parameters were observed at the final week of assessment (week 18). Analysis of variance (ANOVA) revealed highly significant differences ($P \leq 0.01$) among treatments for plant height, canopy area, number of leaves, leaf surface area, and root length (Table 1).

Plants treated with low salinity (3 ppt, T1) exhibited growth metrics comparable to the control (TC), while moderate (6 ppt, T2) and high salinity (9 ppt, T3) treatments resulted in notable growth reductions (Table 2). Specifically, plant height and root length were most affected under T3, indicating that high salt concentration severely inhibits vertical and underground biomass development. These findings align with prior studies showing that increasing salinity levels inhibit root elongation and shoot development due to osmotic imbalance and ion toxicity (Munns & Tester, 2008; Hakim et al., 2010).

Table 1: Mean square values from ANOVA for growth traits of *Solanum melongena* at final harvest (week 18).

Parameter	Salinity (df=3)	Block (df=2)	Error (df=54)
Plant height (cm)	1681.58**	994.15**	74.36
Canopy area (cm²)	5,417,826.26**	4,124,823.25**	269,333.44
Leaf number	529.00**	418.87**	20.96
Leaf surface area (cm²)	46,758.12**	43,139.42**	3,138.00
Root length (cm)	587.55**	403.23**	24.77

Table 2: Mean values of growth parameters for *Solanum melongena* under different salinity levels.

Treatment	Height (cm)	Canopy (cm²)	Leaf number	Leaf area (cm²)	Root length (cm)
TC (0.03 ppt)	31.25^{a}	1353.0^{a}	15.07^{a}	140.41^{a}	19.40^{a}
T1 (3 ppt)	32.78^{a}	1243.6^{a}	12.53^{a}	140.44^{a}	18.25^{a}
T2 (6 ppt)	19.93^{b}	453.0^{b}	5.27^{b}	72.48^{b}	11.23^{b}
T3 (9 ppt)	10.18^{c}	121.2^{c}	2.47^{c}	26.32^{c}	6.10^{c}

(*Different superscripts indicate significant differences at $P \leq 0.05$.*)

3.2 Growth Pattern Over Time

Weekly data collection from week 11 to 18 revealed significant interactions between salinity level and plant age for plant height, canopy area, leaf number, and leaf surface area ($P \leq 0.01$) (Table 3). Across all growth stages, T1 treatment maintained performance similar to control, while T2 and especially T3 significantly reduced plant growth.

Table 3: ANOVA for weekly growth data across treatments.

Source	Plant Height	Canopy Area	Leaf Number	Leaf Area
Salinity (3 df)	5422.36**	16,399,021.68**	1354.24**	214,250.50**
Week (7 df)	2497.28**	5,680,816.14**	122.90**	67,620.40**
Treatment × Week (21 df)	188.71**	984,519.69**	47.13**	7,288.78**
Error (446 df)	45.63	215,197.4	10.92	2,292.63

Growth patterns showed a linear increase for TC and T1, while growth in T2 and T3 treatments plateaued or declined (Figures 1–4). T3 treatment stunted plant height by ~62% compared to TC. High salinity resulted in fewer leaves and smaller canopy and leaf areas, likely due to ion toxicity and osmotic stress affecting cell division and expansion (Munns et al., 2006; Parida & Das, 2005).

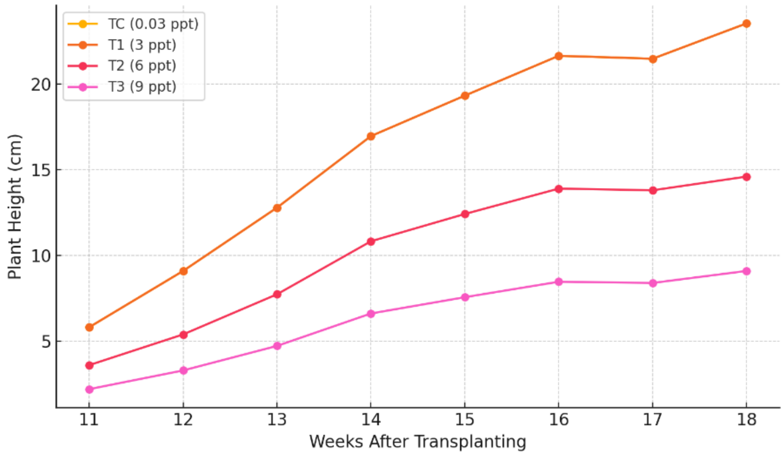

Fig. 1: Effect of salinity on plant height of eggplant

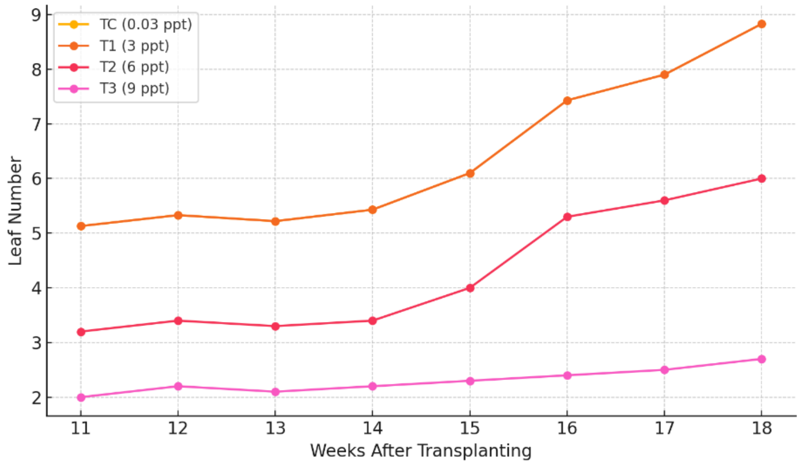

Fig. 2: Effect of salinity on number of leaves of eggplant

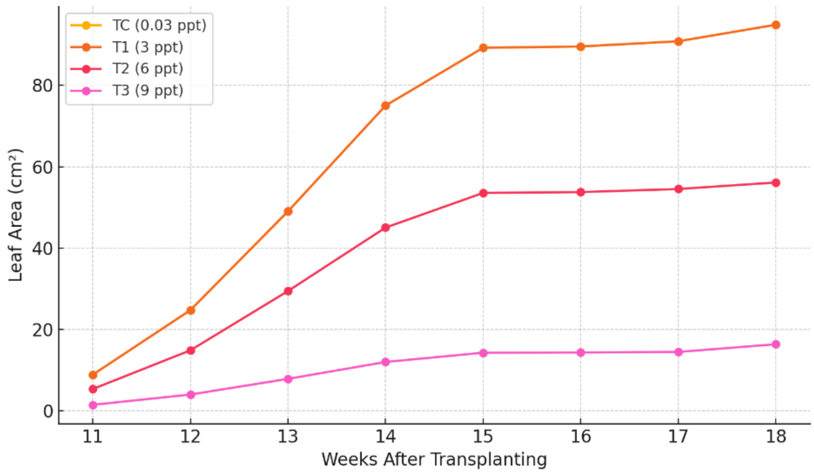

Fig. 3: Effect of salinity on leaf area of eggplant

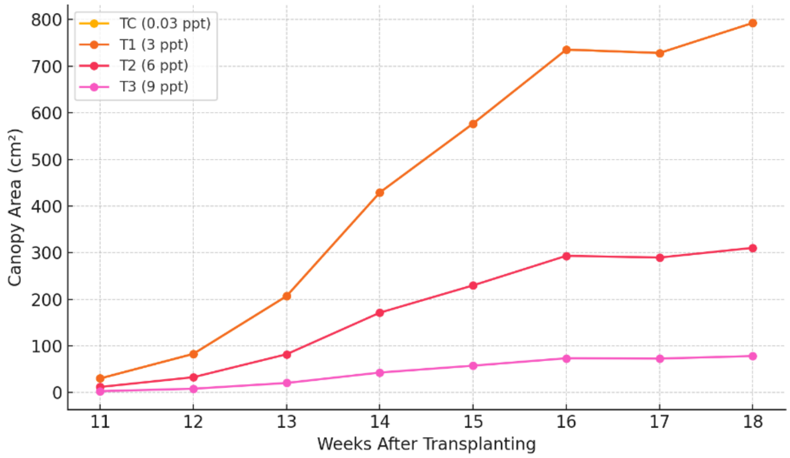

Fig. 4: Effect of salinity on canopy area of eggplant

Root development was significantly inhibited under T2 and T3 conditions, suggesting that high salt concentration impairs water and nutrient uptake (Hakim et al., 2010). Reduced root length translates to poor shoot growth, as roots are primary organs for water and mineral acquisition (Jeannette et al., 2002). The control and T1 plants developed longer roots and taller shoots, supporting their greater resilience to mild salinity.

Salinity-induced stress likely caused ionic imbalances and reduced photosynthetic efficiency, leading to leaf senescence, as observed in T3 (Santa-Cruz et al., 2002). Visual symptoms such as chlorosis, necrosis, and early leaf drop were prevalent in T3. The accumulation of Na^+ and Cl^- ions may exceed the cellular detoxification capacity, damaging cellular organelles (Munns, 2005).

Consistent with findings by Wu et al. (2012), high salinity reduced chlorophyll content and photosynthesis rate, which could explain the reduced leaf number and surface area in high salinity treatments. Moreover, the osmotic effect of salinity likely caused reduced water potential, leading to impaired turgor pressure and cellular expansion (Maathuis, 2006; Hasegawa et al., 2000).

5. Conclusion

This study confirms that elevated salinity levels adversely affect the growth of *Solanum melongena* L. All measured parameters plant height, canopy area, number of leaves, leaf surface area, and root length declined significantly with increasing salinity. The plants exposed to 6 ppt and 9 ppt treatments (T2 and T3) exhibited signs of osmotic stress, reduced water uptake, and nutrient deficiency, resulting in stunted growth and poor physiological performance. However, the 3 ppt treatment (T1) did not significantly impair most growth traits compared to the control, indicating that eggplant can tolerate mild saline conditions up to 3 ppt without severe developmental penalties.

These findings suggest that *S. melongena* could be a viable crop option in slightly saline soils, especially in regions facing early-stage soil salinization. However, salinity levels above 3 ppt pose considerable stress and are detrimental to vegetative growth. Future work should investigate physiological and molecular mechanisms of salinity tolerance in eggplant cultivars and explore mitigation strategies such as the use of organic amendments, salt-tolerant rootstocks, or microbial biostimulants.

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Conflict of Interest

The authors declare no conflicts of interest.

References

Akinci, I. E., Akinci, S., Yilmaz, K., & Dikici, H. (2004). Response of eggplant varieties (*Solanum melongena*) to salinity in germination and seedling stages. *New Zealand Journal of Crop and Horticultural Science, 32*(2), 193–200. https://doi.org/10.1080/01140671.2004.9514292

Chaudhary, S., Kanwar, M. K., Bhardwaj, R., & Sharma, A. (2022). Salt stress and plant growth: Understanding mechanisms and strategies for crop improvement. *Plant Stress, 3*, 100067. https://doi.org/10.1016/j.stress.2021.100067

Daunay, M. C., Lester, R. N., & Gebhardt, C. (2021). Eggplant. In C. Kole (Ed.), *Wild crop relatives: Genomic and breeding resources* (pp. 295–313). Springer. https://doi.org/10.1007/978-3-642-21101-0_16

FAO. (2021). *Global map of salt-affected soils*. Food and Agriculture Organization of the United Nations. https://doi.org/10.4060/cb9918en

Frary, A., Doğanlar, S., Daunay, M. C., & Tanksley, S. D. (2007). Eggplant. In *Genome Mapping and Molecular Breeding in Plants* (pp. 231–257). Springer. https://doi.org/10.1007/978-3-540-34536-7_13

Hakim, M. A., Juraimi, A. S., Begum, M., Hanafi, M. M., & Ismail, M. R. (2010). The effect of salinity on growth, ion accumulation and salt tolerance of rice varieties. *Australian Journal of Crop Science, 4*(3), 169–174.

Hasanuzzaman, M., Nahar, K., Fujita, M., & Islam, M. T. (2021). Plant responses and tolerance to salt stress: Physiological and biochemical mechanisms. In M. Hasanuzzaman et al. (Eds.), *Plant Abiotic Stress Tolerance* (pp. 23–76). Springer. https://doi.org/10.1007/978-3-030-72803-0_2

Hasegawa, P. M., Bressan, R. A., Zhu, J. K., & Bohnert, H. J. (2000). Plant cellular and molecular responses to high salinity. *Annual Review of Plant Biology, 51*, 463–499. https://doi.org/10.1146/annurev.arplant.51.1.463

Heuer, B., Meiri, A., & Shalhevet, J. (1986). Salt tolerance of eggplant. *Plant and Soil, 95*(1), 9–13. https://doi.org/10.1007/BF02377105

Hossain, M. A., Uddin, M. K., Ismail, M. R., & Ashrafuzzaman, M. (2012). Responses of glutamine synthetase–glutamate synthase cycle enzymes in tomato leaves under salinity stress. *International Journal of Agriculture and Biology, 14*, 509–515.

Jeannette, E., Roubelakis-Angelakis, K. A., & Boyer, N. (2002). Salt stress and plant growth. In Pessarakli, M. (Ed.), *Handbook of Plant and Crop Physiology* (pp. 453–472). CRC Press.

Jha, U. C., Bohra, A., Jha, R., Chaturvedi, S. K., & Soren, K. R. (2023). Salt stress in crop plants: Understanding molecular mechanisms and potential breeding strategies. *Frontiers in Plant Science, 14*, 1117035. https://doi.org/10.3389/fpls.2023.1117035

Kashyap, V., Dhiman, M. R., Ram, R. B., & Srivastava, K. (2003). Evaluation of brinjal (*Solanum melongena* L.) germplasm under sodic soil conditions. *Vegetable Science, 30*(1), 76–78.

Kumar, N., Guleria, S., & Sharma, D. R. (2022). Eggplant (*Solanum melongena* L.): Nutritional composition and health benefits. *Vegetos, 35*, 1346–1354. https://doi.org/10.1007/s42535-022-00343-5

Maas, E. V. (1984). Salt tolerance of plants. In R. J. Hagan et al. (Eds.), *Handbook of Plant Science in Agriculture* (pp. 57–75). CRC Press.

Maathuis, F. J. M. (2006). The role of monovalent cation transporters in plant responses to salinity. *Journal of Experimental Botany, 57*(5), 1137–1147. https://doi.org/10.1093/jxb/erj117

Munns, R. (2002). Comparative physiology of salt and water stress. *Plant, Cell & Environment, 25*(2), 239–250. https://doi.org/10.1046/j.0016-8025.2001.00808.x

Munns, R. (2005). Genes and salt tolerance: bringing them together. *New Phytologist, 167*(3), 645–663. https://doi.org/10.1111/j.1469-8137.2005.01487.x

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *Annual Review of Plant Biology, 59*, 651–681. https://doi.org/10.1146/annurev.arplant.59.032607.092911

Parida, A. K., & Das, A. B. (2005). Salt tolerance and salinity effects on plants: A review. *Ecotoxicology and Environmental Safety, 60*(3), 324–349. https://doi.org/10.1016/j.ecoenv.2004.06.010

Rengasamy, P. (2006). World salinization with emphasis on Australia. *Journal of Experimental Botany, 57*(5), 1017–1023. https://doi.org/10.1093/jxb/erj108

Roslan, Z. A., Ahmad, D., & Arifin, A. (2019). Climate change impact on coastal agriculture: The case of salinity intrusion and adaptation in Malaysia. *IOP Conference Series: Earth and Environmental Science, 298*, 012020. https://doi.org/10.1088/1755-1315/298/1/012020

Santa-Cruz, A., Martinez-Rodriguez, M. M., Perez-Alfocea, F., Romero-Aranda, R., & Bolarin, M. C. (2002). The rootstock effect on the tomato salinity response depends on the shoot genotype. *Plant Science, 162*(6), 825–831. https://doi.org/10.1016/S0168-9452(02)00038-8

Savvas, D., & Lenz, F. (1996). Influence of salinity on the incidence of blossom-end rot in tomato grown on rockwool. *Journal of Horticultural Science, 71*(3), 313–320. https://doi.org/10.1080/14620316.1996.11515313

Shrivastava, P., & Kumar, R. (2015). Soil salinity: A serious environmental issue and plant growth promoting bacteria as one of the tools for its alleviation. *Saudi Journal of Biological Sciences, 22*(2), 123–131. https://doi.org/10.1016/j.sjbs.2014.12.001

Unlukara, A., Kurunc, A., Kesmez, G. D., Yurtseven, E., & Suarez, D. L. (2010). Effects of salinity on eggplant (*Solanum melongena* L.) growth and evapotranspiration. *Irrigation and Drainage, 59*(2), 203–214. https://doi.org/10.1002/ird.491

Wu, X. X., Zhu, Z. W., Li, X. L., & Zuo, C. (2012). Effects of 24-epibrassinolide on photosynthesis of eggplant (*Solanum melongena* L.) seedlings under salt stress. *Photosynthetica, 50*(3), 389–396. https://doi.org/10.1007/s11099-012-0036-z

Zörb, C., Geilfus, C. M., & Dietz, K. J. (2019). Salinity and crop yield. *Plant Biology, 21*(S1), 31–38. https://doi.org/10.1111/plb.12884